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(71) Applicants and

(72) Inventors: **MOORE, Kevin, M.** [US/US]; 1510 Alexander Drive, Mt. Zion, IL 62549 (US). **SANBORN, Alexandra, Jan** [US/US]; 1865 Tiffany Avenue, Lincoln, IL 62656 (US).

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(74) Agents: **LUDWIG, Steven, R.** et al.; Sterne, Kessler, Goldstein & Fox P.L.L.C., 1100 New York Avenue, N.W., Suite 600, Washington, DC 20005-3934 (US).

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(54) Title: PROCESS FOR THE PRODUCTION OF ANHYDROSUGAR ALCOHOLS

(57) Abstract: A process is provided for the preparation of anhydrosugar alcohols. The process involves heating a sugar alcohol or a monoanhydrosugar alcohol starting material in the presence of an acid catalyst, and subsequent purification of the anhydrosugar alcohol. Very high purities are achieved, without the use of organic solvents in the process.

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Process for the Production of Anhydrosugar Alcohols

Field of the Invention

5 The present invention relates to the production of anhydrosugar alcohols. More particularly, the present invention relates to a process for the production of anhydrosugar alcohols from sugar alcohols that does not require the use of organic solvents.

Background

10 The chemical formation of closed-ring organic molecules has posed many issues for structural organic chemists. This has been particularly true with regard to synthetic reactions involving sugars and polyols, the acid dehydration of which leads to internal anhydro compounds (mono- and dianhydro products). Fleche and Huchette, *Staerke*, 38 (1985) 26-30.

15 The earliest work in this area was done on 1,4:3,6 – dianhydro-D-mannitol by Fauconnier in 1884. Only sporadic work followed until the 1940's and 1950's, when intensive work was done on all possible isomers of 1,4:3,6 – dianhydro-hexitols. Stoss and Hemmer, *Adv. Carbohydrate Chem. and Biochem.* (1991) 93-173. Since then a large body of chemical literature has developed in this area.

20 The 1,5:3,6 – dianhydrohexitols belong to the so-called “biomass-derived substances”, obtainable from natural products. Therefore, these compounds are classified as “regenerable resources.” Furthermore, 1,4:3,6 – dianhydrohexitols, such as isosorbide, can be used as starting materials and intermediates in various organic synthetic reaction schemes. For example, 25 isosorbide is useful in the formation of numerous pharmaceutical compounds, in food production, cosmetic production, plastic and polymer production, and in other industrial uses such as in the production of polyurethane, polycarbonate, polyesters, and polyamides. Stoss and Hemmer, 1991.

30 Of the known isohexides, isosorbide is considered to be that of the highest importance. Stoss and Hemmer (1991) describe the putative steps leading from D-glucitol (also referred to in the art as sorbitol) to isosorbide.

Acidic media are generally used for dehydrating the sugar alcohol substrate. Especially to enhance the yield and to avoid side reactions, certain modifications of the reaction conditions have been employed over the years, with various impacts on yield of isosorbide product. Stoss and Hemmer,
5 1991.

Several processes for the production of anhydrosugar alcohols (including isohexides such as isosorbide) are known. See, for example, PCT application number PCT/US99/00537 (WO 00/14081), collecting methods and disclosing a continuous production method with recycling of organic solvent.
10 Most methods involve the use of concentrated acids and organic solvents. Goodwin et al. (*Carbohydrate Res.* 79 (1980), 133-141) have disclosed a method involving the use of acidic-cation-exchange resin in place of concentrated, corrosive acids, but with low yield of isosorbide product. An alternative, supersaturation-based method is disclosed in U.S. Patent No.
15 4,564,692 (Feldmann et al., Jan. 14, 1986). However, a need continues in the art for a process for production of very pure isosorbide, at reasonable yields, and preferably without the use of potentially hazardous organic solvents.

Summary of the Invention

20 The present invention relates to a process for the preparation of anhydrosugar alcohols from sugar alcohol starting materials. The process results in very pure products, with relatively high yields, without the use of organic solvents.

In general, the process involves the heating of the appropriate sugar
25 alcohol starting material, with stirring, until molten; dehydrating the molten starting material in the presence of an appropriate catalyst (e.g., a soluble acid or an acidic ion exchange resin), with stirring, and under vacuum at elevated temperature; purifying the anhydrosugar alcohol, for example by distillation, and then by melt crystallization and/or redistillation; and isolating the final,
30 purified product (for example, by centrifugation or, alternatively, by filtration).

Detailed Description

The present invention provides a solvent-free process for the production of very pure anhydrosugar alcohols. The process of the invention generally includes the steps of melting a sugar alcohol starting material, maintaining the elevated temperature and adding an appropriate catalyst and applying a vacuum, with stirring, for a length of time (which will depend upon the reaction conditions) sufficient to remove all water. The resultant anhydrosugar alcohol mixture is then subjected to a purification and separation process, and an anhydrosugar alcohol product of high purity is produced.

Typical sugar alcohols, particularly pentites and hexites, are suitable for use as starting materials in the process of the invention. The starting materials can include sugar alcohols, monoanhydrosugar alcohols, or a mixture of such alcohols. Generally the preferred starting materials include arabinitol, ribitol, D-glucitol (also referred to in the art as D-sorbitol or sorbitol, and referred to herein as sorbitol), D-mannitol (or mannitol), galactitol (dulcitol), iditol, and the like. Sorbitol is a particularly preferred starting material because it is readily available, and because pure isosorbide is very useful in a number of chemical and pharmaceutical applications.

In the first step of the process of the present invention, the selected starting material is melted. If, by way of example, sorbitol is the starting material, it is heated to at least about 100°C, or at least to its melting point. For anhydrosugar alcohols generally this temperature is from about 100°C to about 191°. For sorbitol powder, to provide a specific example, the preferred melting temperature is from about 98°C to about 105°C; an even more preferred melting temperature is from about 98°C to about 100°C. Once molten, the sorbitol is subjected to stirring.

A catalyst that will facilitate the dehydration of the sugar alcohol is then added to the molten starting material. Typically the catalysts used to facilitate the dehydration of sugar alcohols are acid catalysts. The classes of acid catalysts useful in the practice of the present invention are soluble acids,

acidic ion resins, and inorganic ion exchange materials. Therefore, acids such as sulfuric acid, phosphoric acid, p-toluenesulfonic acid, p-methanesulfonic acid, and the like, are preferred for use in the present invention. Alternatively, for example, Zeolite powders such as CBV 3024 or CBV 5534G (available from Zeolist International), or T-2665 or T-4480 (available from United Catalysis, Inc.), or the like, can be used in the practice of the invention. More preferred are acidic ion resins such as AG50W-X12 from BioRad Laboratories, Amberlyst 15 or 35 from Rohm & Hass, and RCP21H from Mitsubishi Chemical Corp., as well as Dowex 50Wx4 (Dow Chemical Co.).
Amberlyst 35 is a particularly preferred resin in the practice of the present invention, specifically for the production of isosorbide from sorbitol.

The amount of catalyst used will vary depending upon the reaction conditions and starting material, as those of skill in the art will appreciate, but will generally be on the order of from about 0.01 equivalents to about 0.15 equivalents by weight. The currently preferred amount of catalyst is 0.1 equivalents by weight.

It is possible to perform one or two dehydrations of the starting sugar alcohol during the reaction, producing a mono- or dianhydrosugar alcohol. The reaction may also be controlled so as to produce a combination of mono- and dianhydrosugar alcohols by adjusting either the reaction conditions or the starting materials, which as those of skill in the art will appreciate, could contain both sugar alcohols and monoanhydrosugar alcohols.

The dehydration in the presence of the catalyst is carried out under a vacuum, at elevated temperatures, and with stirring of the reaction mixture. The vacuum can range over a pressure of from about .05 Torr to about 40 Torr, with preferred pressures of from about 1 Torr to about 10 Torr. As a specific example, the currently preferred pressure for the dehydration step in the process of the present invention in which isosorbide is made from sorbitol is from about 1 Torr to about 10 Torr. In the production of isosorbide from sorbitol, the dehydration is carried out for approximately 2 hrs, with constant stirring, at a temperature of about 120°C. The water is pulled off of the melted

sorbitol/catalyst mixture under a vacuum of from about 1 Torr to about 10 Torr.

It will of course be appreciated by those of skill in the art that, in a process such as that of the present invention, which involves application of both elevated temperatures and vacuum, the specific parameters of the process, including the time it takes to carry certain steps to completion, will vary depending upon the temperatures and pressures used. As one of skill in the art would anticipate, for example, the inventors have determined that higher vacuum levels for the distillation step gave the expected lower distillation temperature. An additional variable is the selected starting material, which will have a particular melting and/or distillation point (the latter, of course, being dependent upon the vacuum). This is equally true for the purification process described below. However, given the disclosure presented herein, it is within the level of skill in the art to optimize the process parameters of the invention for a particular application. This can be done with only a few preliminary experiments, and without undue experimentation, in light of the instant disclosure.

Following the dehydration procedure, the resultant mixture is purified. In a preferred embodiment, vacuum distillation is used, although alternatives such as filtration, or the addition of activated charcoal with subsequent crystallization, are available. As noted above, the parameters for vacuum distillation will vary depending upon the material to be purified, and the temperature and pressure, as will be appreciated by those of ordinary skill in the art. The pot temperature will of course depend upon the temperature at which the material to be purified distills (the distillation point), which again will depend on the vacuum applied in the system. For example, in the case of isosorbide, a range of vapor temperatures of from about 155°C to about 170°C is preferred; more preferred is from about 160°C to about 170°C; even more preferred is from about 165°C to about 170°C. The vacuum pressure can be from about .05 Torr to about 40 Torr; preferably from about 1 Torr to about 10 Torr. For example, and specifically with regard to vacuum distillation of isosorbide, a vacuum pressure of from about 1 Torr to about 10 Torr, a pot

temperature of about 180°C and a vapor temperature of from about 160°C to about 170°C are currently most preferred.

In order to further purify and isolate the anhydrosugar alcohol, the anhydrosugar alcohol distillate is subjected to melt crystallization. The recovered distillate product is heated to its melting point (e.g., for isosorbide, to approximately 65°C) until molten, and then cooled over time until the crystallization point is reached, but not so much that the material solidifies. In fact, a slurry-like consistency is preferred, so that the material can be centrifuged. The centrifugation is performed at a relatively high speed for a relatively short period of time, again in order to avoid solidification of the material, and also to avoid having the desired purified anhydrosugar alcohol end product be drawn off with the remaining impurities. The resultant anhydrosugar alcohol product should be at least 98% pure, and in most cases will be >99% pure (depending upon the solidity of the "slurry").

The present invention is described in further detail in the following non-limiting examples.

Example 1

This Example describes the production of very high purity isosorbide from sorbitol using a particularly preferred embodiment of the process of the present invention.

Sorbitol powder (180.6 grams, 0.99 mol) was placed in a 3-neck round bottom flask equipped with an agitator, temperature probe, and vacuum line. The sorbitol was heated to approximately 100°C until molten. An acidic ion exchange resin, Amberlyst 35 (Rhom & Haas) (19.8 grams) was added and vacuum was applied at from about 1 Torr to about 10 Torr. The temperature was increased to from about 120°C to about 130°C. These temperature and vacuum parameters were maintained for approximately 2 hours, with constant stirring. The resultant mixture was then vacuum distilled at from about 1 Torr to about 10 Torr, pot temperature of 180°C, vapor temperature of 170°C. The distillate was collected and subjected to melt crystallization by heating to approximately 65°C until molten, then cooling, over about 30 minutes to about

45 minutes to approximately 35°C, at which temperature a slurry-like solution was formed. This solution was then quickly centrifuged (in order to avoid solidification), and the resultant isosorbide product had a purity of 99.3%, with an overall yield of 48%.

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Example 2

The same apparatus and the same operational conditions-except those specified below-as in Example 1 were used. Upon heating sorbitol to ~100°C to a molten state, an acidic ion exchange resin, Amberlyst 15 (Rohm and Haas, 24.2g), was added and vacuumed applied (5-7 Torr). Heating was increased to 135°C and the reaction allowed to stir continuously for ~2h. The resulting mixture contained 64.5% isosorbide and was then purified by the procedure described in Example 1.

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Example 3

The same apparatus and the same operational conditions-except those specified below-as in Example 1 were used. Upon heating sorbitol to ~100°C to a molten state, an acidic ion exchange resin, Dowex 50WX4, (18.1g), was added and vacuumed applied (7-9 Torr). Heating was increased to 135°C and the reaction allowed to stir continuously for ~2h. The reaction mixture contained 64.1% isosorbide. Purification was then performed.

20

Example 4

The same apparatus and the same operational conditions-except those specified below-as in Example 1 were used. Upon heating sorbitol to ~100°C to a molten state, the acidic ion exchange resin, Amberlyst 35 (Rohm and Haas, 11.7 g), was added and vacuumed applied (9-12 Torr). Heating was increased to 135°C and the reaction allowed to stir continuously for ~2h. The

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resulting mixture contained 18.6% sorbitan and 73.4% isosorbide. The mixture was then purified using the above described procedure.

Example 5

5 The same apparatus and the same operational conditions-except those specified below-as in Example 1 were used. Upon heating sorbitol to ~100°C to a molten state, the acidic ion exchange resin, RCP21H (Mitsubishi Chemical Corporation, 12.9 g), was added and vacuumed applied (7-9 Torr). Heating was increased to 135°C and the reaction allowed to stir continuously
10 under vacuum for ~5h. The resulting mixture contained 68.9% isosorbide. The mixture was then purified using the above described procedure.

Example 6

15 The same apparatus and operational conditions-except those specified below-as in Example 1 were used. Sorbitol (221.4 g, 0.99 mol) was heated to ~100°C to a molten state. At this time, a sulfated zirconia pellet (#416/03 Japan Energy Corporation, 57.7 g), was added and vacuumed applied (5-7 Torr). Heating was increased to 150°C and the reaction allowed to stir continuously for ~7h. The resulting mixture contained 2.2% sorbitol, 56.0%
20 sorbitan and 22.9% isosorbide.

 Having now fully described the present invention in some detail by way of illustration and example for purposes of clarity of understanding, it will be obvious to one of ordinary skill in the art that the invention can be performed by modifying or changing the invention with a wide and equivalent
25 range of conditions, formulations and other parameters thereof. Furthermore, it will be obvious to the skilled practitioner that such modifications or changes are intended to be encompassed within the scope of the appended claims.

 All publications, patents and patent applications mentioned in this specification are indicative of the level of skill of those skilled in the art to
30 which this invention pertains, and are herein incorporated by reference to the

same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated by reference.

What Is Claimed Is:

1. A process for the production of an anhydrosugar alcohol, without using organic solvents, the process comprising:

5 heating a selected sugar alcohol or monoanhydrosugar alcohol starting material, with stirring, until molten;

dehydrating the starting material, under vacuum and while maintaining heat and stirring, in the presence of an acid catalyst to produce a dehydrated anhydrosugar alcohol mixture; and

10 purifying the anhydrosugar alcohol.

2. The process of Claim 1 wherein the acid catalyst is a soluble acid.

3. The process of Claim 2 wherein the acid catalyst is selected from the group consisting of sulfuric acid, phosphoric acid, p-toluenesulfonic acid, and
15 p-methanesulfonic acid.

4. The process of Claim 1 wherein the acid catalyst is a zeolyte powder.

5. The process of Claim 4 wherein the zeolyte powder is selected from
20 the group consisting of CBV 3024, 5534G, T-2665, and T-4480.

6. The process of Claim 1 wherein the acid catalyst is an acidic ion exchange resin.

7. The process of Claim 6 wherein the acidic ion exchange resin is
25 selected from the group consisting of AG50W-X12, Amberlyst 35, Amberlyst 15, RCP21H, and Dowex 50Wx4.

8. The process of Claim 6 wherein the acidic ion exchange resin is added
30 in an amount giving from about 0.01 to about 0.15 gram equivalents of resin to sugar alcohol.

9. The process of Claim 1 wherein the purification comprises vacuum distillation of the dehydrated anhydrosugar alcohol mixture followed by melt crystallization.

5 10. The process of Claim 1 wherein the purification comprises vacuum distillation of the dehydrated anhydrosugar alcohol mixture followed by a re-distillation.

10 11. The process of Claim 1, further comprising a final separation of the anhydrosugar alcohol by centrifugation.

12. The process of Claim 1, further comprising a final separation of the anhydrosugar alcohol by filtration.

15 13. A process for the production of an anhydrosugar alcohol, without using organic solvents, the process comprising:

heating a selected sugar alcohol or monoanhydrosugar alcohol starting material, with stirring, until molten;

20 dehydrating the molten starting material, under vacuum and while maintaining heat and stirring, in the presence of an acid catalyst, to produce a dehydrated anhydrosugar alcohol mixture;

vacuum distilling the dehydrated anhydrosugar alcohol mixture to produce an anhydrosugar alcohol distillate;

25 melt crystallizing the anhydrosugar alcohol distillate to produce a crystallized anhydrosugar alcohol product; and

centrifuging the crystallized anhydrosugar alcohol product to produce a very pure anhydrosugar alcohol.

30 14. The process of Claim 13 wherein the acid catalyst comprises a soluble acid.

15. The process of Claim 14 wherein the soluble acid is selected from the group consisting of sulfuric acid, phosphoric acid, p-toluenesulfonic acid, and p-methanesulfonic acid.

5 16. The process of Claim 13 wherein the acid catalyst comprises a zeolyte powder.

17. The process of Claim 16 wherein the zeolyte powder is selected from the group consisting of CBV 3024, CBV 5534G, T-2665, and T-4480.

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18. The process of Claim 13 wherein the acid catalyst comprises an acidic ion exchange resin.

15 19. The process of Claim 18 wherein the acidic ion exchange resin is selected from the group consisting of CBV 3024, CBV 5534G, T-2665, T-4480, AG50W-X12, Amberlyst 15, Amberlyst 35, RCP21H, and Dowex 50Wx4.

20 20. The process of Claim 13 wherein the dehydration is performed at a temperature of from about 98°C to about 191°C.

21. The process of Claim 13 wherein the dehydration is performed at a temperature of from about 98°C to about 130°C.

25 22. The process of Claim 13 wherein the dehydration is performed at a temperature of from about 98°C to about 120°C.

23. The process of Claim 13 wherein the dehydration is performed at a vacuum pressure of from about .01 Torr to about 40 Torr.

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24. The process of Claim 13 wherein the dehydration is performed at a vacuum pressure of from about 0.1 Torr to about 10 Torr.

25. The process of Claim 13 wherein the dehydration is performed at a vacuum pressure of from about 1 Torr to about 10 Torr.

5 26. The process of Claim 13 wherein the vacuum distillation is performed at a vapor temperature of from about 155°C to about 170°C and a pot temperature of at least the distilling point of the dehydrated anhydrosugar alcohol.

10 27. The process of Claim 13 wherein the vacuum distillation is performed at a vapor temperature of from about 160°C to about 170°C and a pot temperature of at least the distilling point of the dehydrated anhydrosugar alcohol.

15 28. The process of Claim 13 wherein the vacuum distillation is performed at a vapor temperature of from about 165°C to about 170°C and a pot temperature of at least the distillation point of the dehydrated anhydrosugar alcohol.

20 29. The process of Claim 13 wherein the vacuum distillation is performed at a vapor temperature of 170°C and a pot temperature of at least the distillation point of the dehydrated anhydrosugar alcohol.

25 30. The process of Claim 13 wherein the vacuum distillation is performed at a vacuum pressure of from about .01 Torr to about 40 Torr.

31. The process of Claim 13 wherein the vacuum distillation is performed at a vacuum pressure of from about 0.1 Torr to about 10 Torr.

30 32. The process of Claim 13 wherein the vacuum distillation is performed at a vacuum pressure of from about 1 Torr to about 10 Torr.

33. A process for the production of purified isosorbide, without the use of organic solvents, the process comprising:

heating sorbitol powder at a temperature of from about 98°C to about 105°C, with stirring, until molten;

5 dehydrating the melted sorbitol by catalysis with an acidic ion exchange resin, added in an amount giving from about 0.01 to about .15 equivalents, under vacuum pressure of from about 1 Torr to about 10 Torr, and while maintaining stirring and temperature, to form an isosorbide mixture;

10 vacuum distilling the dehydrated isosorbide at a pot temperature of approximately 180°C and a vapor temperature of approximately 170°C, and a vacuum pressure of from about 1 Torr to about 10 Torr, to form an isosorbide distillate;

15 melt crystallizing the isosorbide distillate by heating the distillate to at least approximately 65°C and then cooling the distillate, over from about 30 minutes to about 45 minutes, to a temperature of about 25°C to about 35°C to form a slurry-like isosorbide solution;

centrifuging the isosorbide solution and;

collecting the purified isosorbide.

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER

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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C07D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, BEILSTEIN Data, CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 4 861 513 A (LUEDERS HARALD ET AL) 29 August 1989 (1989-08-29) claim 1; example 1	1-33
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X	US 4 564 692 A (FELDMANN JOHN ET AL) 14 January 1986 (1986-01-14) cited in the application claim 1	1-33

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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Seelmann, I

INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

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(71) Applicant (for all designated States except US):
ARCHER-DANIELS-MIDLAND COMPANY
[US/US]; 4666 Faries Parkway, Box 1470, Decatur,
Illinois 62525 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **MOORE, Kevin, M.**
[US/US]; 1510 Alexander Drive, Mt. Zion, IL 62549 (US).
SANBORN, Alexandra, Jan [US/US]; 1865 Tiffany Av-
enue, Lincoln, IL 62656 (US).

(74) Agents: **LUDWIG, Steven, R.** et al.; Sterne, Kessler,
Goldstein & Fox P.L.L.C., 1100 New York Avenue, N.W.,
Suite 600, Washington, DC 20005-3934 (US).

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(54) Title: PROCESS FOR THE PRODUCTION OF ANHYDROSUGAR ALCOHOLS

(57) Abstract: A process is provided for the preparation of anhydrosugar alcohols. The process involves heating a sugar alcohol or a monoanhydrosugar alcohol starting material in the presence of an acid catalyst, and subsequent purification of the anhydrosugar alcohol. Very high purities are achieved, without the use of organic solvents in the process.

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